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(54) **Composite elongate element**

(57) A composite elongate element, made for example by pultrusion and of thermosetting or thermoplastic synthetic resin reinforced with glass or carbon filaments, comprises continuous reinforcing filaments which extend in the length direction of the element. The cross-sectional shape e.g. rectangular of the element varies along its length, but the cross-sectional area of the element is substantially constant. As a result, filament continuity is maintained throughout the length of the element. The element may function as a monoleaf spring, or as a structural beam.

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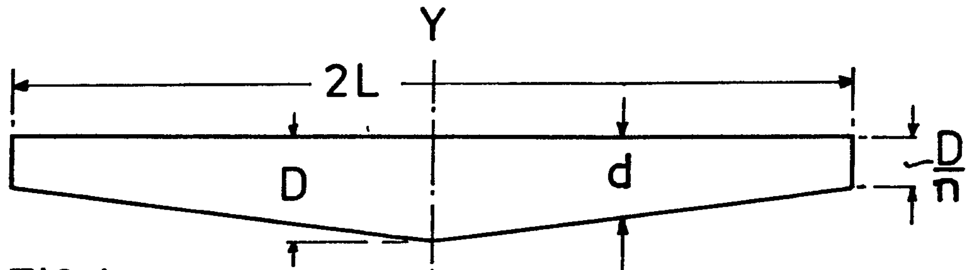

FIG. 1

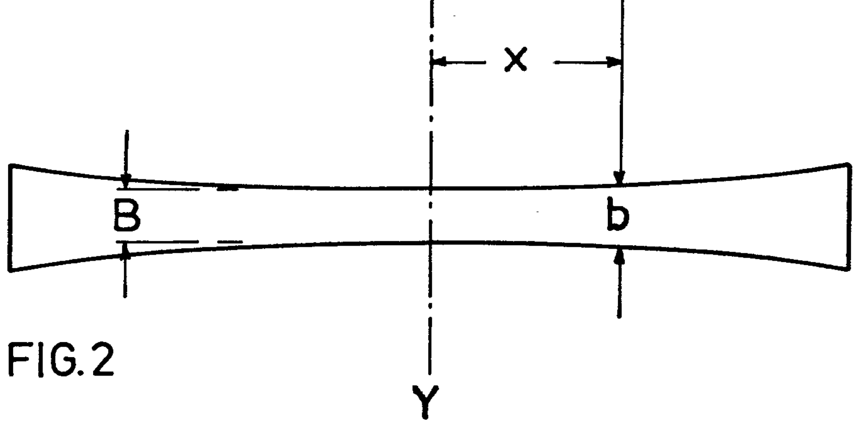

FIG. 2

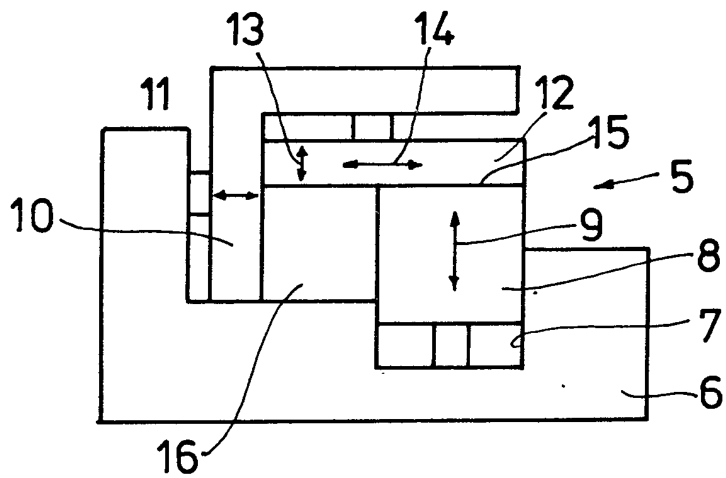

FIG. 3

SPECIFICATION

Composite element

The present invention relates to a composite elongate element reinforced by continuous filaments.

It is often desirable to reinforce composite elements with continuous filaments but present methods of manufacturing such elements involve cutting tapes made of continuous filaments pre-impregnated with resin to required lengths, positioning the cut tapes in a mould and carrying out a pressing operation to shape the composite element. Such a procedure is laborious and expensive and the present invention seeks to simplify the production of composite elongate elements.

According to the invention, a composite elongate element, reinforced with continuous filaments extending in the length direction of the element, has a cross-sectional shape which varies along the length of the element and a cross-sectional area which remains constant or is subject to only insubstantial change throughout the length of the element, with the result that filament continuity is maintained throughout the length of the element without significant change in the specific properties of the element along its length.

By accepting the design limitation that the cross-sectional area of the element shall not be subject to substantial change, the element can be made from a single block of filament reinforced resin thus obviating the need to build up a block for moulding from a number of pieces of pre-impregnated tape.

The invention thus includes a method of manufacturing a composite elongate element reinforced with continuous filaments, the method including making an elongate member comprising a synthetic resin reinforced with continuous filaments extending in the length direction of the member and shaping the elongate member so as to vary its transverse cross-sectional shape along its length whilst maintaining the transverse cross-sectional area of the member constant or subject to only insubstantial change throughout the length of the member, thereby maintaining filament continuity in the member and producing a composite element having specific properties not subject to significant change along the length of the element.

The invention will be further described, by way of example, with reference to the accompanying drawing in which,

Figure 1 is an elevation of a monoleaf spring according to the invention,

Figure 2 is a plan of the spring of Fig. 1, and

Figure 3 is a diagrammatic end view of a pultrusion die for use in carrying out the method of the invention.

A conventional monoleaf vehicle spring has a cross-sectional area which varies along the length of the spring in order to create a balance between the requirements of strength and flexibility. The spring normally has a greater depth in the centre to cater for high bending stresses in this region and has a smaller cross-section in its end regions where the bending stresses are lower and shear loads are of greater importance. The smaller cross-section in the end regions increases the flexibility of the spring and enables it to perform its duties with reduced weight of material.

Spring weights can be reduced further by making the springs from composite materials comprising synthetic resins reinforced by fibres. It is desirable that fibres are used which are continuous throughout the length of the spring but the cost of making a composite spring containing reinforcement comprising continuous filaments is high, since to make such springs it has been necessary to cut pre-impregnated fibre tapes to length, position the tapes in a mould one by one and finally carry out a pressing operation to form the composite spring. In a typical spring this may involve handling more than 200 cut tapes.

If, however, the spring is designed so that its cross-sectional area remains constant, or substantially constant, throughout its length, the manufacturing procedure can be simplified.

Let it be assumed that it is desired to manufacture a monoleaf spring of rectangular transverse cross-section which, seen from the side, has the shape shown in Fig. 1. This spring is symmetrical about the line Y–Y, the two halves of the spring on each side of the line Y–Y being of trapezoidal shape of maximum depth D and minimum depth D/n, n being a positive number greater than unity. If the length of the spring is 2L, then the depth d of the spring at any distance x from the line Y–Y, on either side of the latter, is given by the equation

$$d = D\left(1 - \frac{n-1}{n} \cdot \frac{x}{L}\right) \qquad (1)$$

If the spring is to have a constant cross-sectional area A throughout its length, the breadth b of the spring (see Fig. 2) at any distance x from the line Y–Y, on either side of the latter, must satisfy the equation

$$b.d = A \qquad (2)$$

From equations (1) and (2) this means that

$$b = \frac{A}{D}\left(\frac{1}{1 - \frac{n-1}{n} \cdot \frac{x}{L}}\right) \qquad (3)$$

If the minimum breadth of the spring at the line Y–Y is to be equal to B, this means that the equation for the curvature of the sides of the spring is given by the equation

$$b = B\left(\frac{1}{1 - \frac{n-1}{n} \cdot \frac{x}{L}}\right) \qquad (4)$$

Thus, a spring having dimensions which satisfy equation (1) above will have a constant transverse cross-sectional area throughout its length if the sides of the spring are curved in accordance with equation (4). The strength of the spring is maintained by the increased depth at its centre and its flexibility increase towards its extremities. By altering the rate at which the depth decreases towards the ends of the spring, the flexibility of the spring can be altered.

One method of manufacturing the spring shown in Figs. 1 and 2 is to pultrude continuous reinforcing filaments in an uncured or partly cured synthetic thermosetting or thermoplastic resin to form a pultruded member having a cross-sectional area equal or substantially equal to that required in the spring. The pultruded member is then cut into lengths and each length is pressed in a mould to shape it to the form required for the spring which will have a cross-section of varying shape but of constant cross-section along its length. The mould may be heated to cure, or complete the curing of, the resin.

During the pressing operation, the reinforcing filaments migrate to accommodate changes in the cross-section of the pultruded member with the result that some filament paths become longer than others. Thus some of the filaments may be "drawn in" at the ends of the pultruded member and in order to produce a spring having reinforcing filaments extending throughout its length it will then be necessary to cut off the end portions of the pultruded member to produce the final shaped element. This must be allowed for in choosing the length of the mould and the length of the initial pultruded member.

In order further to simplify the manufacturing procedure, the pultrusion process may be carried out using a die 5 as shown in Fig. 3 having variable geometry.

The die 5 comprises a base 6 formed with a channel 7 in which a side member 8 is slidable in the directions shown by arrows 9. Another side member 10 is slidable on the base 6 in directions shown by the arrows 11 and a top member 12 is slidable on the side member 10 in directions shown by the arrows 13 and 14, the arrangement being such that the member 12 is maintained in close contact with a plane upper surface 15 of the side member 8. Means for effecting sliding movement of the members 8, 10 and 12 are not shown in Fig. 3 but may comprise hydraulic piston-and-cylinder devices which are controlled so as to cause movement of the members such as to alter the aspect ratio of the rectangular die orifice 16 and thus of the pultruded member in accordance with predetermined criteria.

As a result, the pultrusion process produces a member of rectangular section of varying shape along its length. Thus, in carrying out the pultrusion process, an elongate member comprising a synthetic resin reinforced with continuous filaments extending in the length direction of the member is formed and the member is then pultruded through the die of Fig. 3, the aspect ratio of the die being adjusted during the process so as to shape the element according to predetermined criteria, such as those laid down above for the spring of Figs. 1 and 2. The cross-sectional area of the pultruded member is thus maintained constant, or substantially constant, whilst its cross-sectional shape varies along its length.

The principle of constant cross-sectional area with variable geometry may be applied to elements other than vehicle springs, for example, structural members in aircraft and support beams in civil engineering. The principle enables the properties of fibre reinforced plastic beams to be tailored to specific end uses in a continuous production process. The resultant elements demonstrate high material utilisation.

If in manufacturing elements according to the invention if is desired to alter the cross-sectional area of the element along its length, this may be done if continuity is maintained by increasing the volume fraction of synthetic resin is the composite material, the number of reinforcing filaments remaining constant. The variation may be carried to a point where the specific properties of the composite material (that is the properties of unit and in general a variation of 10% in cross-sectional area is likely to be attainable but a greater variation may be possible in some cases.

The reinforcing filaments in the composite elongate elements according to the invention may comprise, for example, carbon fibre, glass fibre, boron fibre or an aromatic polyamide such as the material sold under the trade name "Kevlar" by E.I. du Pont de Nemours and Company. The resin in the composite elongate elements may be a synthetic thermosetting or thermoplastic resin, for example a polyamide or a polyester.

CLAIMS

1. A composite elongate element reinforced with continuous filaments extending in the length direction of the element, the element having a cross-sectional shape which varies along the length of the element and a cross-sectional area which remains constant or is subject to only insubstantial change throughout the length of the element, with the result that filament continuity is maintained throughout the length of the element without significant change in the specific properties of the element along its length.

2. A composite element as claimed in claim 1 constituted by a monoleaf spring, at least a portion of the spring in the length direction having a rectangular transverse cross-section, a trapezoidal upright longitudinal cross-section and parallel end faces, wherein the maximum depth (at one end of said portion) of the trapezoidal cross-section is D and its minimum depth (at the opposite end of said portion) is D/n where n is a positive number greater than unity, the same portion of the spring has a horizontal longitudinal cross-section with parallel ends and sides curving symmetrically outwardly from the end of the portion of the spring with the maximum depth to the end of the portion of the spring with the minimum depth, and wherein the length of said portion of the spring is L, the depth d of the trapezoidal cross-section of the spring at a distance x from said end of maximum depth is given by the equation

$$d = D\left(1 - \frac{n-1}{n} \quad \frac{x}{L}\right)$$

and the curvature of the sides of said horizontal longitudinal section of the spring is represented by the equation

$$b = B\left(\frac{1}{1 - \frac{n-1}{n} \cdot \frac{x}{L}}\right)$$

wherein the minimum breadth of the spring is B and b is the breadth of the spring portion at the distance x from the end of maximum depth.

3. A composite elongate element reinforced with continuous filament extending in the length direction of the element, constructed and arranged substantially as hereinbefore described with reference to, and as illustrated in, Figs. 1 and 2 of the accompanying drawing.

4. A method of manufacturing a composite elongate element reinforced with continuous filaments, the method including making an elongate member comprising a synthetic resin reinforced with continuous filaments extending in the length direction of the member and shaping the elongate member so as to vary its transverse cross-sectional shape along its length whilst maintaining the transverse cross-sectional area of the member constant or subject to only insubstantial change throughout the length of the member, thereby maintaining filament continuity in the member and producing a composite element having specific properties not subject to significant change along the length of the element.

5. A method as claimed in claim 4, comprising the steps of pultruding continuous reinforcing filaments in an uncured or partly cured synthetic thermosetting or thermoplastic resin to form a pultruded member having a cross-sectional area equal or substantially equal to that required in the finished composite element, and pressing the pultruded member in a mould to shape it to the desired form of the finished composite element.

6. A method of manufacturing a composite elongate element reinforced with continuous filaments, the method being substantially as hereinbefore described with reference to Fig. 3 of the accompanying drawing.

7. A composite elongate element whenever made by the method claimed in any of claims 4 to 6.

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ABSTRACT:

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